ILLINOIS NATURAL HISTORY SURVEY

Growth and Survival of Nearshore Fishes in Lake Michigan

F-138-R-1

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Annual Report
to
Division of Fisheries
Illinois Department of Natural Resources

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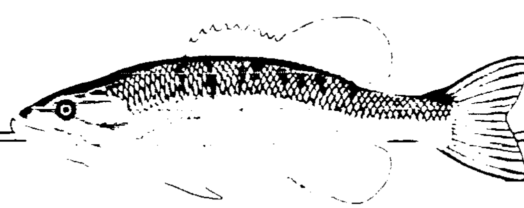
October 1999



Aquatic Ecology Technical Report 99/12

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August 1, 1998 – July 31, 1999

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submitted to
Division of Fisheries, Illinois Department of Natural Resources
in fulfillment of the reporting requirements of
Federal Aid Project F-138-R

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October 1999

This study is conducted under a memorandum of understanding between the Illinois Department of Natural Resources and the Board of Trustees of the University of Illinois. The actual research is performed by the Illinois Natural History Survey, a division of the Illinois Department of Natural Resources. The project is supported through Federal Aid in Sport Fish Restoration by the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not the Illinois Department of Natural Resources.

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EXECUTIVE SUMMARY

This report summarizes the first year of a three-year project that began in August 1998. The purpose of this project is to determine the factors that contribute to and determine the year-class strength of fishes in the nearshore waters of Lake Michigan. This research focused on the Illinois waters of Lake Michigan due to the limited data on year-class strength and recruitment of nearshore fishes. Primarily this research will attempt to generate patterns of year-class strength based on a set of factors that allow managers to better predict interannual fluctuations in fish populations.

After this project was funded, we learned that an artificial reef would be built at one of our nearshore sites. Little quantitative information exists on the role such reefs play on the recruitment success of fishes in freshwater. Consequently we sampled the reef site (plus a nearby reference site) as part of our usual sampling to identify how the reef might alter production of food for fishes, recruitment success, and other possible effects in the nearshore fish community.

The objectives of this study are to 1) quantify the abundance, composition, and growth of nearshore larval and young-of-year (YOY) fish in selected locations along the Illinois shoreline of Lake Michigan, 2) quantify the abundance and composition of zooplankton and benthic invertebrates in selected locations along the Illinois shoreline of Lake Michigan, 3) explain whether any predictive patterns of year class strength for nearshore fish can be generated from the biotic and abiotic data, and 4) experimentally determine effects of food availability on the growth and survival of nearshore fishes.

Because Segment 1 data are currently being processed, the results and discussion of this report are preliminary and should be interpreted as such. Further, some objectives are based on a time series and will be addressed across several segments, therefore, results for each objective will not be specifically discussed in this report.

1. Surface temperatures are warmer at sites in the southern nearshore than in the north. Southern water temperatures warmed faster and experienced less fluctuation in weekly temperature compared to northern sites.
2. Preliminary analyses suggest that densities of zooplankton are greater at the southern sites than northern sites. Zebra mussel veligers were abundant in plankton samples in the south, whereas they were not present in northern samples.
3. The number of larval fish collected in the south was greater than catches in the north. Species composition also differed, with yellow perch dominating southern sites and cyprinids dominating in the north. Few larval alewife have been identified in the ichthyoplankton samples to date. Larval fish catch decreased significantly after 17 June 1999.
4. Trawling was not an effective sampling method in the south; on dates where fish were collected only the round goby and yellow perch caught. Age-1 and adult alewife, ninespine stickleback, rainbow smelt, and spottail shiner dominated species composition of trawl catches in the north. Meanwhile, bloater, yellow perch, trout-perch, and sculpin were less common. Few age-0 fish of any species were collected through July 31.

5. All benthic samples have been collected and sieved; organisms currently are being picked from the debris. Over the next six months organisms will be identified and enumerated.
6. Line-transect surveys indicate that the round goby is the primary inhabit of the reef and control sites
7. Artificial substrates were placed at the reef (n=6) and control (n=6) sites to monitor colonization rates of benthic invertebrates. Substrate bags will be recovered in October, 1999 (Segment 2).

INTRODUCTION

Research began in August 1998 to determine the factors that contribute to and determine the year-class strength of fishes in the nearshore waters of Lake Michigan. The primary goal of this research is to explore mechanisms regulating year-class strength such that managers can better predict interannual fluctuations in fish populations. This report summarizes the first year of a three-year project.

A "year-class" or cohort of fish is a group of individuals that is spawned in a given year (i.e. 1998 year-class), and the number of individuals in that group that survive or "recruit" to the adult population defines the "strength" of that year-class. Growth and survival of larval and juvenile fish are the primary early indicators of year-class strength. Year class strength and recruitment can be influenced by many density-independent and density-dependent factors. Fluctuations in water temperature or food availability (Houde 1994), storm or wind events (Mion et al. 1998), and predation (Letcher et al. 1996), can affect growth and survival of fishes. For instance, growth is closely related to water temperatures (Letcher et al. 1997) and minor changes in daily growth can cause major changes in recruitment (Houde 1987). An overlap in the distribution of species (i.e. alewife, *Alosa pseudoharengus*; rainbow smelt, *Osmerus mordax*) may reduce the fitness of one or both species if they compete for a limiting resource like zooplankton (Stewart et al. 1981). Favorable abiotic and biotic conditions have been linked to year-class strength and recruitment to the adult population. Therefore, understanding the factors that determine success at early life stages will help to predict fluctuations and overall success of the adult population.

Managing fish populations in a system as vast and dynamic as Lake Michigan can be daunting when all possible variables (i.e. temperature, food availability, fishing, and pollution) are considered. To better manage the nearshore fish assemblage it is important to elucidate the primary factor or factors that regulate fluctuations in fish populations both within and among years. By identifying the factors that affect early life stages, primarily larval and juvenile fish, we can generate models to allow managers to predict interannual fluctuations in the adult population.

The nearshore waters of Lake Michigan support a complex assemblage of fishes. Yellow perch (*Perca flavescens*) and smallmouth bass (*Micropterus dolomieu*) are two major sportfishes, whereas alewife and spottail shiner (*Notropis hudsonius*) are two of the many prey fishes in this habitat. These species experience extensive variability in abundance and several have experienced major decreases in abundance during the last decade. For example, the Lake Michigan yellow perch population supported a thriving commercial and recreational fishery in the late 1980s, but since 1988 the yellow perch population has suffered extremely poor recruitment (Robillard et al. 1999). Analysis of larval fish samples collected at two sites adjacent to Waukegan Harbor (related project F-123-R) from 1988 to 1997 further highlight this variability in fish abundance. Over the ten-year period, yellow perch and alewife larvae comprised 90% of all larval fish collected in the nearshore waters of Lake Michigan (Figure 1a & b), although both species have declined in overall abundance. Larval yellow perch declined in abundance beginning with the 1987 cohort, whereas larval alewife abundance decreased abruptly after a strong cohort in 1994. These results indicate that larval fish abundance can be extremely variable within and between years.

We established several study questions to address year-class strength of Lake Michigan fishes and to determine how year-class strength relates to the adult population. These objectives were designed to explore some of the mechanisms that affect fish recruitment including resource availability and abiotic factors. The objectives are:

- To quantify the abundance, composition, and growth of nearshore larval and young-of-year (YOY) fish in selected locations along the Illinois shoreline of Lake Michigan.
- To quantify the abundance and composition of zooplankton and benthic invertebrates in selected locations along the Illinois shoreline of Lake Michigan.
- Explain whether any predictive patterns of year class strength for nearshore fish can be generated from the biotic and abiotic data.
- Experimentally determine effects of food availability on the growth and survival of nearshore fishes.

The data generated from this project will produce a better understanding of nearshore fish recruitment patterns and improve management of the resource.

After this project was funded, we learned that an artificial reef would be built at one of our sampling sites. Because little quantitative information exists on the role such reefs play on the recruitment success of fishes in freshwater and because we can sample the reef site (plus a nearby reference site) as part of our usual sampling, we also will include in this and future reports data on how the reef might alter production of food for fishes, recruitment success, and other possible effects.

This evaluation is important in the context of our research project because a common justification for constructing artificial reefs is that they can improve recruitment of fishes. However, it is not clear that these structures improve fish recruitment and production (Grossman et al. 1997). In fact, many artificial reefs may increase harvest of fish by attracting both fish and anglers. As a result, if artificial reefs do not generate better recruitment, they may actually reduce population of exploited game fish. By examining larval fish abundance, food availability, and fish density we hope to gain some insight into the possible benefits of an artificial reef for fish recruitment.

STUDY SITES

Sites selection was based on a set of criteria that included water depth (3-10 m), substrate composition (soft to sandy sediments), distance from shore (< 2 mi.), and geographical location (northern or southern) on the Illinois shoreline. The average depth of the Lake Michigan nearshore waters is quite different from north to south along the Illinois shoreline. Bottom bathymetry is steep in the north when compared to the south. As a result waters deeper than 10 m are common within 1-1.5 nm of shore in the north but typically do not occur until 3 nm offshore in the south. Further, depth differences are even more apparent when looking for water > 13 m deep. In the north, these waters can be found 2 nm offshore but in the south those depths are rare within 10 nm of shore.

A total of four sample locations were selected in clusters of two, one cluster in the north near Waukegan Harbor and the other in the south near Jackson Harbor (Figure 2). Sampling northern and southern clusters will facilitate the comparison of two distinct nearshore areas within southern Lake Michigan. In the north cluster a site was selected 2.0 nm north of Waukegan Harbor at the mouth of the Dead River (site N1; Figure 2). N1 was selected because of the proximity to the mouth of the Dead River, a unique occurrence on the Illinois shoreline. A second site just north of Waukegan Harbor (site N2) was chosen primarily for historical value. This site has been sampled since 1986 by a related project (F-123-R).

Site selection in the southern cluster was impeded by the numerous disruptions in the shoreline (i.e. breakwalls; harbors) and the limited deep water (>8 m) within 2 nm from shore. One southern site was chosen directly offshore of Jackson Harbor (site S1) and the other was selected approximately 1.2 nm south of Jackson Harbor (site S2) just North of the 78th street water filtration plant. These sites are suitable for sampling and have water depths ranging from 3-9 m with intermittent pockets of water 10 m deep.

Two additional sampling locations were chosen to evaluate artificial reef success. The reef site was selected by the Illinois Department of Natural Resources (IDNR) and is slated to be constructed between October 1999 and May 2000 approximately 1.5 nm offshore of the Museum of Science and Industry in 7.5 m of water. The reef is situated within the S1 sampling zone. A second site was selected as a control to permit comparisons between the reef site and an undisturbed site. The control site is located at a depth of 7.5-m approximately 1.5 nm offshore within site S2.

METHODS

All sites were sampled every other week, weather permitting, except for N2 where data were collected weekly in conjunction with F-123-R. Sampling began in mid-May and will continue through late October. On each date prior to biotic sampling, ambient water temperature and secchi disk depth readings were recorded at each site.

Zooplankton

Replicate zooplankton samples were taken on each date at each site at depths of 7.5 m at the southern sites and 10 m at northern sites. Because zooplankton samples were collected in conjunction with other sampling (i.e. neuston net or trawl), both day and night zooplankton samples were collected at each site. A 73-μm mesh 0.5-m diameter plankton net was towed vertically from 0.5 m above the bottom to the surface. Sampling the entire water column at this depth generates a representative sample of the zooplankton community composition and abundance. Samples were stored immediately in 5% sugar formalin. Zooplankton will be identified and enumerated, and 20 individuals per taxon will be measured to the nearest millimeter.

Invertebrate Sampling

Benthic invertebrates were collected by SCUBA divers at a depth of 7.5 m at each site using a 7.5-cm diameter core sampler. Four replicate samples from the top 7.5 cm of the soft substrate were collected and preserved in 95% ethanol (Fullerton et al. 1998). At the southern sites the sediments were sometimes sampled from the top 3.75 cm when soft to sandy substrate did not exist. Samples were sieved to remove sand and organisms will be picked using sugar flotation. Organism identification will be to the lowest practicable level, likely family; total length (mm) and head capsule width will be measured (mm) for each individual. All taxa will be enumerated and total density estimates will be calculated.

Larval Fish

Larval fish sampling was conducted from mid-May to late-July via a 2x1-m frame neuston net with 500-μm and 1000-μm mesh netting. Neuston samples were taken at night on the surface to collect vertically migrating larval fish. Mesh size was increased prior to sampling on 17 June to adjust for possible net avoidance by larger and more mobile larvae. All samples were collected within 2 nm of shore at depths ranging from 3-10 m for approximately 15 minutes. The volume of water sampled during each tow was determined by fitting the net mouth with a General Oceanics™ flow meter.

Ichthyoplankton samples were preserved in 95% ethanol, sorted, identified and enumerated. In fall 1999 sample identification will be complete and up to 20 individuals from each species will be measured (0.1 mm), and weighed (0.1 mg). In addition, otoliths and the entire digestive tract will be removed from 10 fish per species per date to estimate daily growth and diets (Mion et al. 1998). Otoliths will be mounted and sanded down to expose daily growth rings. Reading daily growth rings allows for the calculation of swimup dates and the back-calculation of individual daily length of larval fish (Ludsin and DeVries 1997). Daily rings are not apparent on otoliths prior to swimup, therefore adjustments will be made to estimate for hatch date (See Ludsin and DeVries 1997). Stomach contents will be identified to the lowest practicable taxonomic classification and measured (mm).

Trawl

Sampling for young-of-year and juvenile fish began in July and will continue through October. Tows of a bottom trawl (4.9-m headrope, 3.8-mm stretch mesh body, and 13-mm mesh cod end liner) were conducted at each site for a distance of 0.5 nm (4519 m^2 of bottom swept) at the 3, 5, 7.5 and 10-m contours. A subsample of fish from each trawl catch was preserved for length, weight, age and diet data. Remaining fish were identified and enumerated in the field and returned to the lake.

Reef sampling

On each date, two SCUBA divers swam a 100-m transect line at the reef and control sites to estimate relative fish composition and abundance. Divers swam on either side of the line and each diver identified and counted fish within a two meter-wide swath along each side of the line. Divers progressed at the same rate along the transect line to maintain equal encounter rate. At the surface divers, documented estimates and discussed the relative size composition of the observed species. Transect data will be used to determine how adding an artificial rock structure to nearshore waters changes the relative composition and abundance of the fish assemblage.

Replicate (n=2) artificial rock structures were deployed at the reef and control sites monthly from July to September to provide information on the dynamics of the aquatic invertebrate community colonizing artificial structures. Each basket held approximately eight rocks and total surface area measurements were taken for each rock basket prior to deployment. When recovered from the lake, all organisms will be removed from the rocks, identified and enumerated.

RESULTS

We report results consisting of data collected from early May to 31 July 1999. Data continue to be processed; thus, these results are a preliminary representation of the entire Segment 1 data set that will be reported in its entirety as part of the Segment 2 report. However, the total numbers of field samples collected through 20 September have been included to demonstrate the types and quantity of samples to be collected during the entire year (Table 1). Differences in the number of samples collected at each site result from additional sampling at some sites by project F-123-R or from cancelled sample outings due to unsafe weather conditions.

Temperature

Surface temperatures in the northern cluster gradually increased from 10°C in late May to 22-24°C in late July (Figure 3a). Bottom temperatures remained lower (8-12°C), exceeding 15°C on only two dates. The obvious difference between surface and bottom temperatures beginning in early June resulted from an established thermocline. N2 periodically experienced warmer temperatures than N1, especially at the bottom, likely resulting from the proximity of N2 to the cooling outflow of a power plant.

Equipment problems and windy conditions hindered measuring early spring water temperatures in the south cluster (Figure 3b). Therefore, data before mid-June are limited to a couple of dates that suggest water temperatures remained low (< 15°C) through mid-June. By 21 June water temperatures had increased to nearly 20°C and were relatively uniform from surface to bottom with less than a 5°C difference. By late July, surface temperatures in the south had exceeded 25°C.

Zooplankton

At total of 149 zooplankton samples were collected at the four sample locations (Table 1). Samples were collected during the day and night to coincide with fish sampling. Preliminary analyses of the samples suggest that densities of zooplankton are greater at the southern sites than northern sites. Veligers of the introduced zebra mussel (*Dreissena polymorpha*) were abundant in plankton samples in the south, whereas they were not present in northern samples.

Larval Fish

A total of 77 ichthyoplankton samples were collected from early May through late July (Table 1). The number of larval fish collected in the south was greater than catches in the north (Figure 4). On 02 June, the catch difference between southern and northern sites approached two orders of magnitude. After 17 June, larval fish catch decreased significantly (Wilcoxon Rank Sum p=0.0001) at all sites, never exceeding one larvae/ 100 m^3. This decline coincided with the mesh size increase from 500 μm to 1000 μm.

Preliminary identification of larval fish indicates that composition differed between north and south. Cyprinid spp. dominated the catch at N1 and N2 whereas yellow perch were a smaller proportion of the species present. However, catches in the south were dominated by larval yellow perch. Larval alewife have been relatively rare in all of the ichthyoplankton samples identified to date.

Trawl

Trawling was an ineffective sampling method in the south. Although sites were selected by substrate type (soft to sandy), intermittent exposure of boulders and bedrock flats covered with zebra mussels repeatedly prevented trawling without getting hung up and even destroyed the trawl. On the dates where fish did remain in the trawl, the round goby (*Neogobius melanostomus*) and yellow perch were the only species present. The following results only represent catches from the northern cluster.

Age-1 and adult alewife, ninespine stickleback (*Pungitius pungitius*), rainbow smelt, and spottail shiner dominated species composition of trawl catches (Figure 4). Meanwhile, bloater, yellow perch, trout perch (*Percopsis omiscomaycus*), and sculpin (*Cottus* sp.) were less common. Ninespine sticklebacks comprised > 60% of the total catch at N1 whereas composition at N2 was evenly distributed among yellow perch, alewife, rainbow smelt, and spottail shiners. Preliminary analysis indicates that YOY yellow perch were first caught on 22 July; however, CPUE has yet to be calculated.

Benthic Sampling

Core samples were collected on five dates at each site from May to September. At the northern sites divers encountered continuous soft sediments (i.e. sandy and silt), meanwhile, the sediments at the southern sites were patchy, consisting of sand, rocks, and bedrock outcroppings. On two dates, variability in sediment types at the southern sites prevented the detection of soft sediment patches large enough to collect every replicate. Therefore on those dates fewer replicate samples were collected.

All benthic samples have been sieved and organisms are being picked from the remaining sand and debris. Over the next six months organisms will be identified and enumerated.

Reef Sampling

We swam transect lines placed on the lake bottom on three dates. The composition of the bottom oriented fish assemblage at the reef and control sites is entirely round goby. However, on 03 August 1999 divers sampling benthic invertebrates did observe twelve adult smallmouth bass roving in the reef area. Only large and small adult round gobies were observed at the reef and control sites through mid-August. On 17 August 1999 three size classes of the round gobies were observed that included equal percentages of large and small adults and YOY round gobies. Transect sampling will continue until mid-October and then resume in the spring after reef construction.

Twelve artificial substrates were placed at the reef (n=6) and control (n=6) sites to monitor colonization rates of benthic invertebrates. Substrate bags will be recovered in early October (Segment 2) and samples will be processed over the next six months.

DISCUSSION

Preliminary results suggest that larval fish density and assemblage composition, as well as the biotic and abiotic factors affecting them, are not uniform across the nearshore waters of Lake Michigan. Although identification of larvae is not yet complete, it appears that larval yellow perch were more abundant in the south, whereas larval cyprinids were more prevalent in the north. There also appear to be year-to-year differences in the larval fish assemblage. For example, in comparison to data collected from other years by related project F-123-R, a relatively strong year-class of larval cyprinids were collected at the northern site. This year-class may have resulted from spawning by the unusually high number of adult spottail shiners collected in the 1998. Spottail shiners comprised 90% of the trawl catch in 1998, a threefold increase from the previous year (Robillard et al. 1999).

Larval alewife were rare in ichthyoplankton samples during 1999. Historically alewife and yellow perch dominated larval catches (Robillard et al. 1999), but in 1999 few alewife have been identified. Several hypotheses could explain the low occurrence of alewife in larval fish samples. A large a spring die-off of spawning adults or a poor year class entering the spawning population (i.e. 1996) affected larval abundance. Upwellings related to wind events have also been identified as decreasing larval alewife abundance by moving larvae offshore (Heufelder et al. 1982). Factors related to sampling including sampling on biweekly intervals, and ending larval sampling in late July are other possible explanations. In addition, increasing mesh size through time to follow growth of early spawned fish may not efficiently collect late spawned larvae.

The northern and southern nearshore areas also exhibited qualitative differences related to temperature and zooplankton. These differences are exemplified by the contrast in larval zebra mussel abundance from north to south. Veligers were absent from northern zooplankton samples, but were extremely abundant in southern samples. These differences, if they remain consistent across years, may lead to fundamentally different mechanisms that affect recruitment of nearshore fishes along a north-south gradient in the Illinois waters of Lake Michigan. For example, water temperatures in the north were generally cooler and exhibited more weekly fluctuation than did the southern sites. Furthermore, the difference between surface and bottom temperature was greater in the north. Water temperature is influential in the timing of fish spawning and fish will spawn at the temperature range that results in the highest survival for their young (Becker 1983). Therefore, fish may spawn several days or weeks earlier in the south compared to the north as a result of warmer water temperatures.

In many aquatic systems, spawning earlier in the spring can be advantageous to recruitment success. Fish that are spawned earlier typically experience a longer growth period during the first summer, grow to a larger size (Letcher et al. 1997), and are more successful surviving through the first winter (Ludsin and DeVries 1997). If this is the case in Lake Michigan, fish that are spawned earlier will have extended feeding and growth periods that should translate to greater recruitment success. However spawning early does not guarantee success in all systems, especially if the appearance of larvae is mismatched with low food availability and/or high predator density (Leggett et al. 1984). In waters around Waukegan, most larval yellow perch first appear when zooplankton densities are <30/L. Because strong recruitment of fishes typically occurs only when zooplankton densities exceed 50/L, yellow perch have been mismatched with their food supply during most of the last decade. Because zooplankton densities typically do not exceed 50/L until sometime in late June or July around Waukegan (Robillard et al. 1999), we predict that those fish that spawn later in the north may be more likely to generate strong year classes if patterns of zooplankton abundance remain consistent. At present, we are unsure whether this same scenario holds for the southern cluster where shallower water depths allow the entire water column to warm more quickly and may allow a more rapid increase in zooplankton density, perhaps favoring recruitment of early spawned fish like yellow perch

If larval fishes can find sufficient zooplankton food to fuel their growth through metamorphosis, older life stages frequently can survive reduced zooplankton. For example, zooplankton frequently crashes during summer in Lake Erie (Wu and Culver 1994), forcing yellow perch to feed on benthic invertebrates, especially chironomids. Yet, in years when yellow perch in Lake Erie switch to benthic invertebrates for a longer period of time, growth of YOY perch is reduced, causing poor year-class strength when compared to years when YOY yellow perch feed predominantly on zooplankton (Dettmers et al., unpublished data).

Benthic invertebrates are important to the function of the aquatic community because they act as an important benthic-pelagic link as prey for many fish species (Covich et al. 1999). Invertebrates primarily inhabit the lake sediments and feed on decaying organic matter or feces and pseudofeces, releasing nutrients back into the environment. Many fish species rely on benthic invertebrates as primary and or secondary food sources. For instance, YOY yellow perch in Lake Erie can switch to feed on benthic invertebrates once the fish grow > 30 mm TL (Wu and Culver 1992). During 1993-1998 when zooplankton was low in abundance in Lake Michigan, invertebrates averaged about 70% of YOY yellow perch diets by number (Robillard et al. 1999). Therefore, benthic invertebrates can be an important link to fish recruitment success, especially as an alternative food source when zooplankton densities are low.

Sampling Modifications

Larval fish catches decreased dramatically after we increased mesh size from 500 μm to 1000 μm in our neuston net. The susceptibility of larval fish to the neuston net is affected primarily by size and swimming behavior. In addition, many species spawn throughout the spring and summer, continually contributing larval fish to the system. The presence of multiple size classes of fish present on a given date makes adjusting mesh size on the neuston net a difficult decision. Based on a complete assessment of the 1999 data, we will decide whether or not to keep the small mesh net throughout the sampling season or to increase mesh size to follow fish growth.

The lack of quantitative trawl data for the southern sites makes assessing the structure and composition of the nearshore juvenile fish assemblage a difficult task.

Because there are no alternative gear types that can collect the same data as the bottom trawl, over the winter we will outfit the trawl with a "rock-hopper" in an attempt to avoid or bounce over the boulders and rock outcroppings.

To compensate for the unsuccessful trawling attempts, gill netting will be conducted at all sites from August to September of segment 2 (1999). Paired gangs of 45.7 m nylon gill nets consisting of three 15.2 m panels (25.4 mm bar; 38 mm bar; 1.75 mm bar) will be set at three-hour intervals at each site. Based on these catches, gill netting will be reevaluated as a suitable sampling method prior to the remainder of the Segment 2 field season that begins in May. We will also explore the potential for beach seining as an option to assess the nearshore fish assemblage.

Reef

Artificial reef construction should be completed by May 2000 and will provide habitat for a number of aquatic organisms. Our observations suggest that the round goby will be a primary inhabitant of the reef. Round gobies are abundant in the reef area and are currently limited to available structures (i.e. intermittent rocks and bedrock outcroppings); thus the addition of a large amount of artificial structure will provide suitable habitat and improve recruitment for the round goby. We expect the zebra mussel will be another early colonizer of the reef because their veligers are present in the water column in this area. Observations and quantitative data collection will continue at the reef and reference sites after the reef is constructed. These data will provide an understanding of the role that artificial reefs may play in the recruitment of nearshore fishes.

Conclusion

Current management strategies for Lake Michigan focus on the nearshore as a contiguous unit. Therefore it is important to determine whether the variable ecological conditions (i.e. temperature and zooplankton) observed across our sites affect growth and survival of the entire nearshore fish assemblage in a predictable way or whether mechanisms operate differently from north to south.

Based on our preliminary and continuing analysis of the data from Segment 1, temperature and zooplankton may be important regulators of the success of nearshore fishes. Qualitatively, we saw very low numbers of alewife larvae, suggesting that the 1999 year-class will be weak. Fewer alewife may have implications for management of salmonids if a consistent trend for reduced alewife becomes apparent. Continued monitoring of larval and juvenile fishes in the context of the abiotic and biotic factors regulating their success is needed to determine 1) whether different mechanisms regulate recruitment in Illinois nearshore waters, 2) how variable recruitment is across years and begin to understand why these fluctuations occur, and 3) appropriate mechanistic models to predict year-class strength of nearshore fishes that can allow better management of these fishes in relation to target harvest levels.

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Table 1. -Summary of the samples collected May-September 1999 at four locations along the Illinois shoreline of Lake Michigan. See text for site description.

	North Sites		South Sites	
Sample Type	N1	N2	S1	S2
Zooplankton	41	56	26	26
Neuston (Larval fish)	16	21	21	19
Trawl (Juvenile/Adult)	49	76	4	8
Gill net (Juvenile/Adult)	6	6	6	6
Benthic cores (Aquatic invertebrates)	20	20	16	17

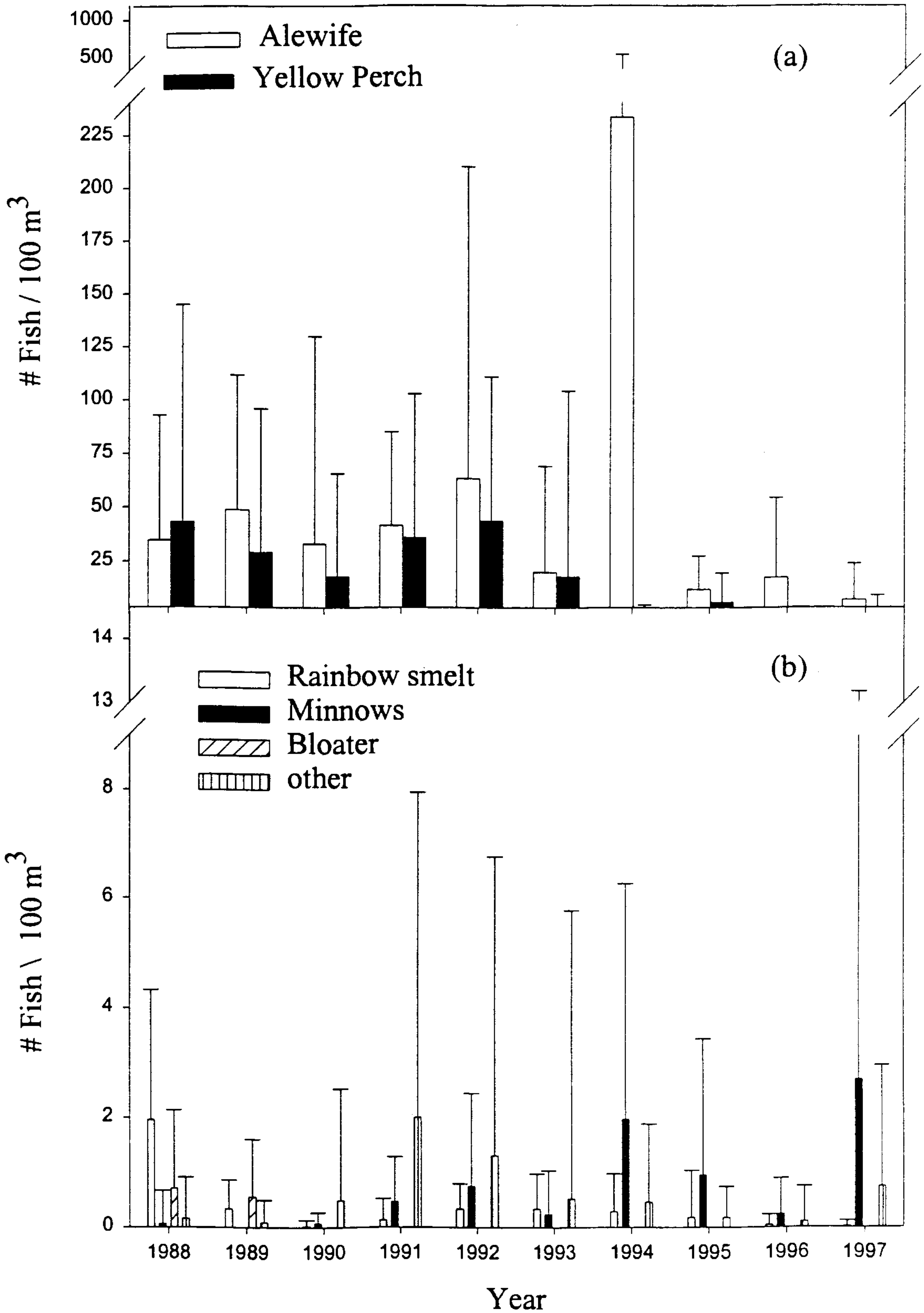

Figure 1.–Mean (+SD) number / 100 m^3 of larval (a) alewife (*Alosa pseudoharangus*) and yellow perch (*Perca flavescens*) and (b) rainbow smelt (*Osmerus mordax*), minow (Cyprinidae sp.), bloater (*Coregonus hoyi*), and other species. Data were collected from 1988 to 1997 at the T3 and T4 sites (see text for description) on Lake Michigan. Note that the scales of the Y axes differ for each figure.

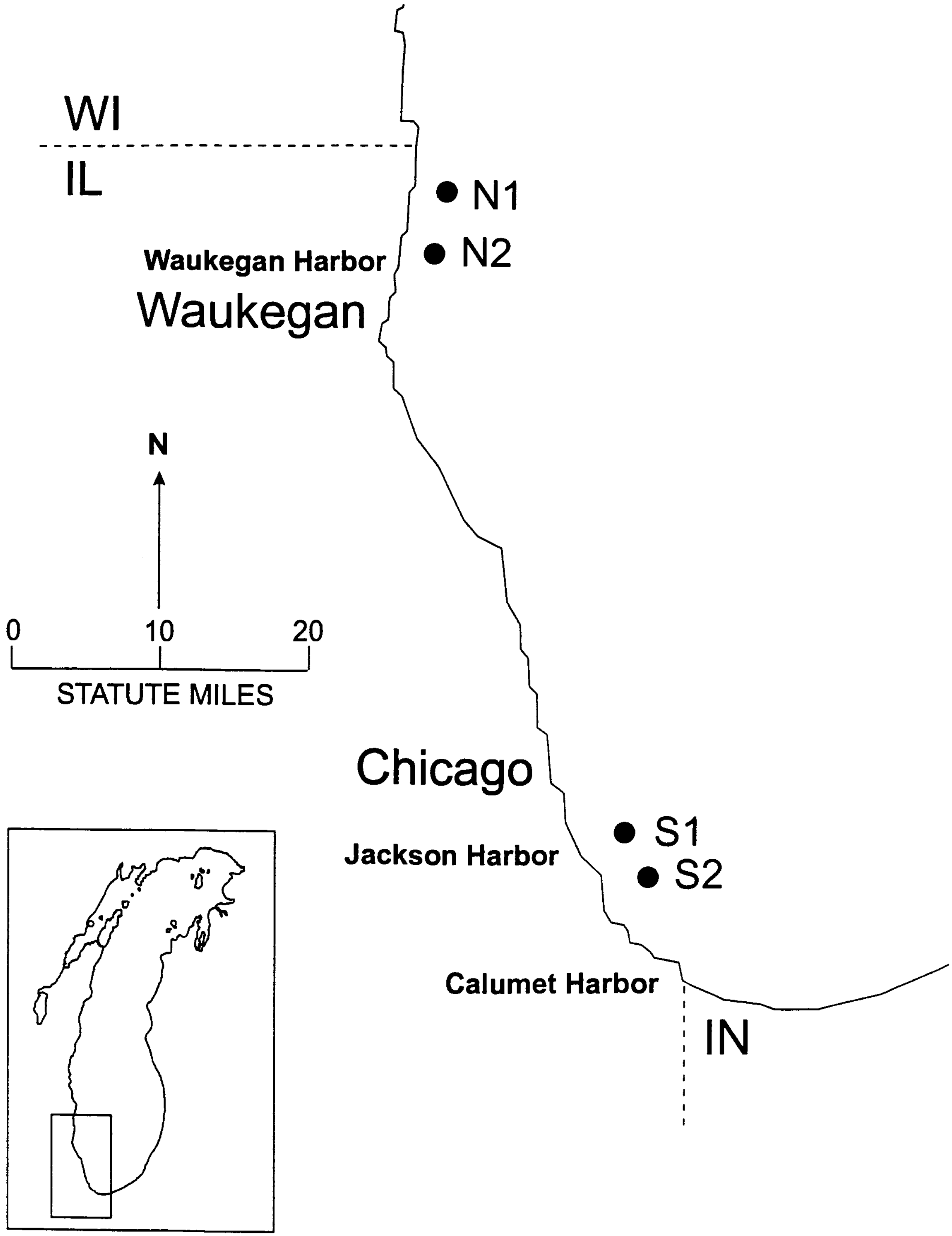

Figure 2. –Nearshore sites sampled along the Illinois shoreline of Lake Michigan. See text for site descriptions.

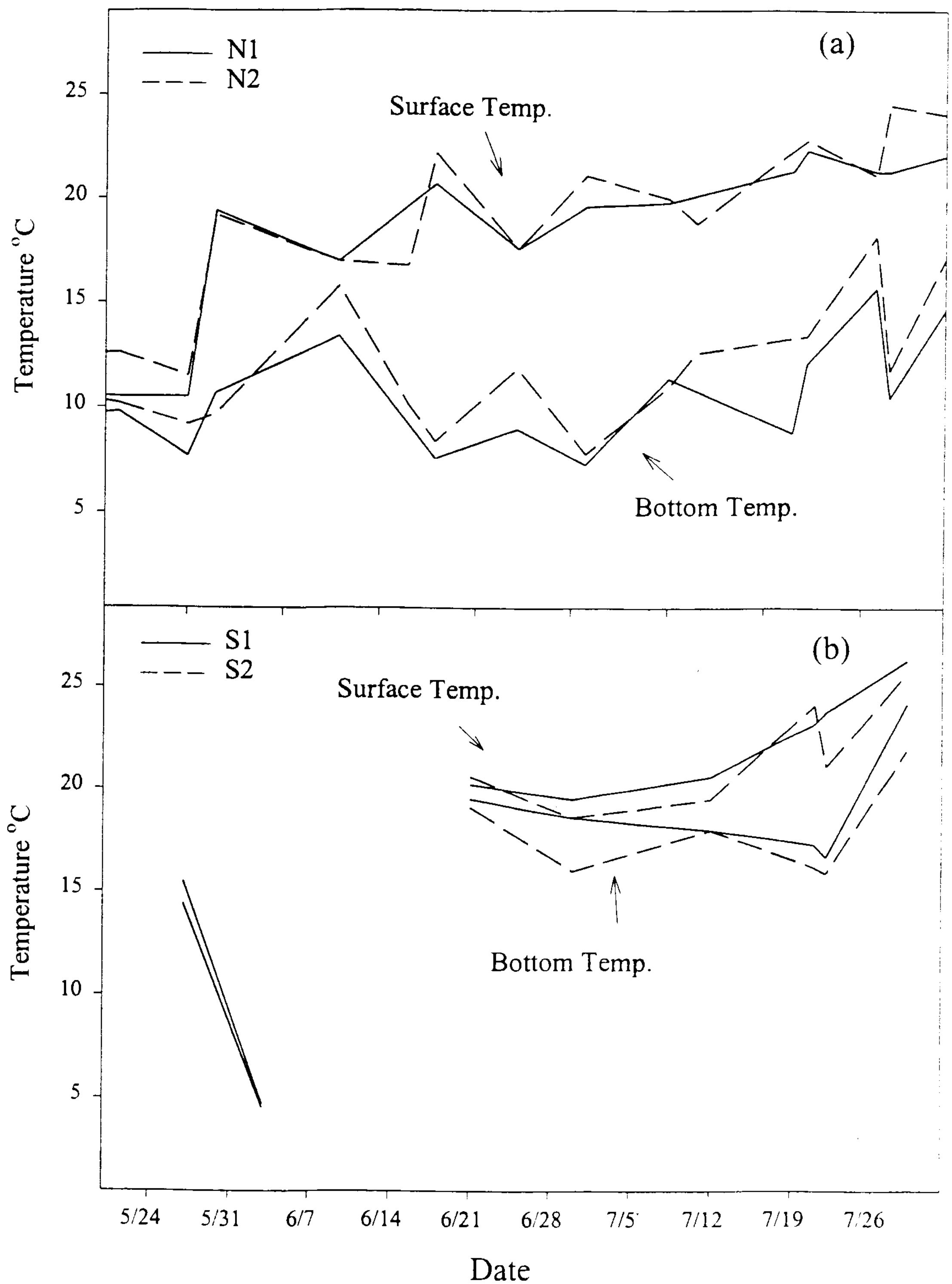

Figure 3. –May-July 1999 water temperatures (surface and bottom) for Lake Michigan at (a) northern (N1 & N2) and (b) southern (S1 & S2) sites.

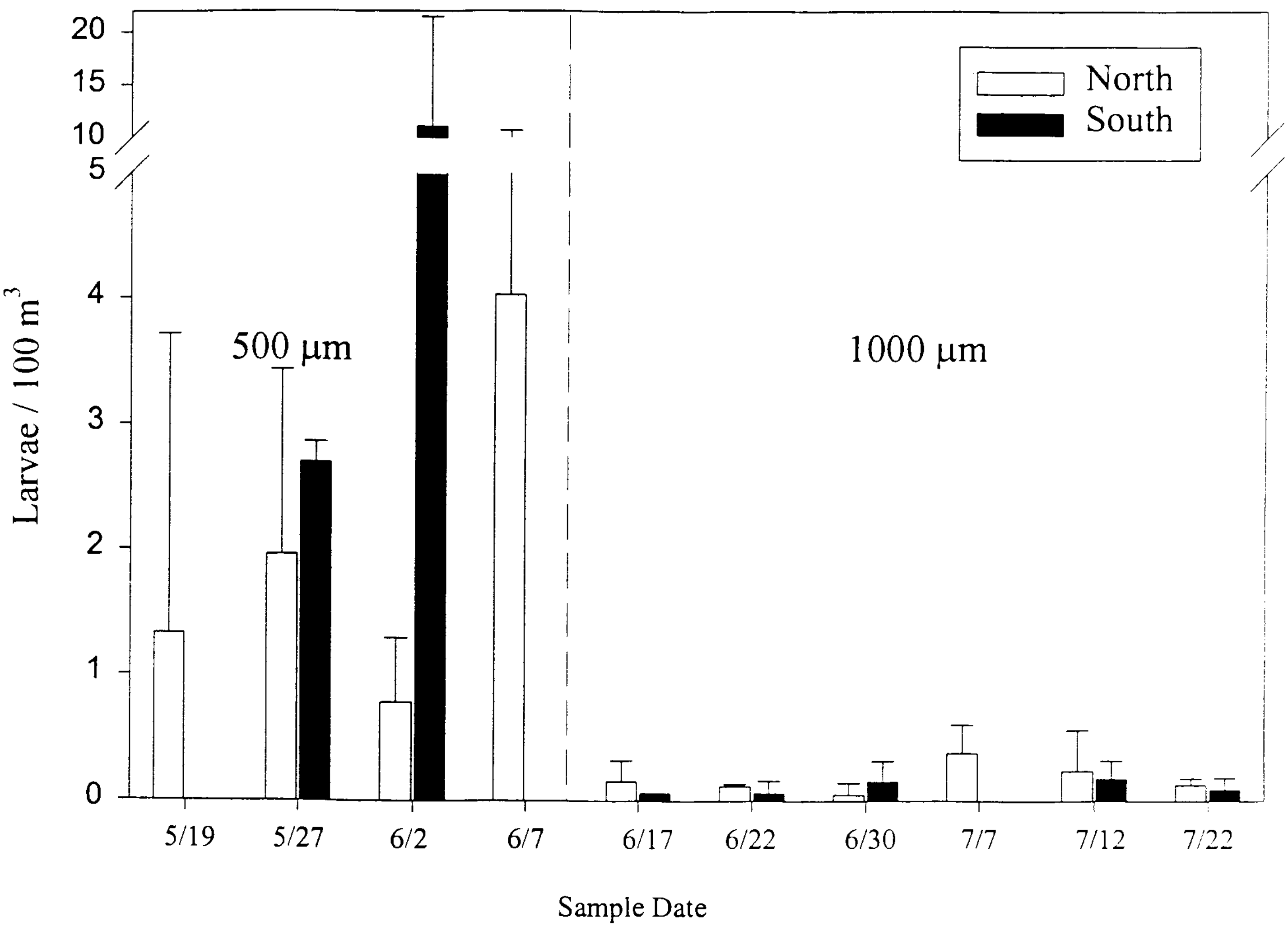

Figure 4. –Mean catch (+SD) of larval fish (larvae / 100 m^3) at four sites, two northern and two southern, along the Illinois shoreline of Lake Michigan. Dashed line indicates a neuston net mesh size increase from 500 to 1000 µm.

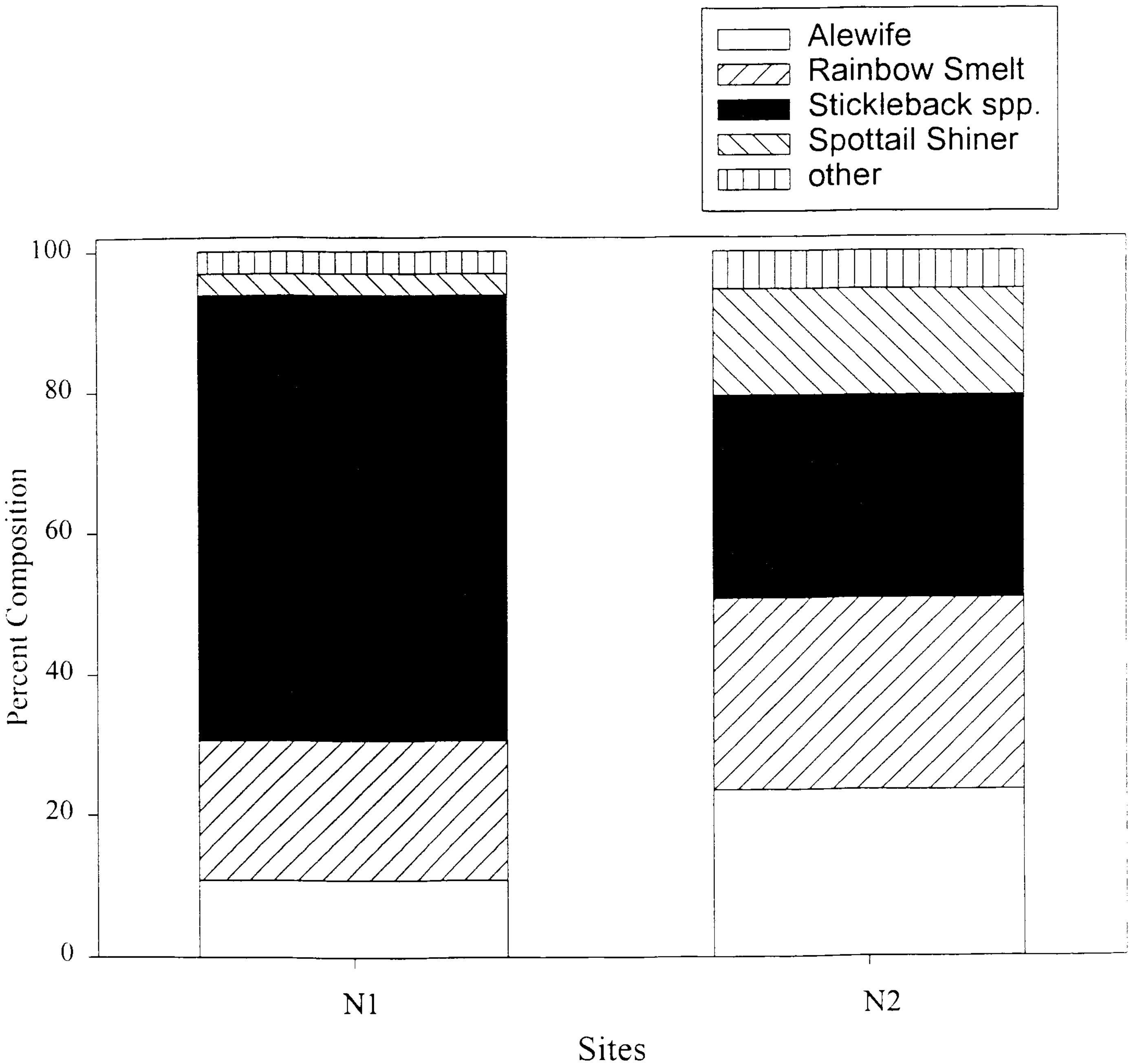

Figure 5. –Percent composition of July trawl catches at the northern sites (N1 & N2).